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Human Consciousness, or Possibilities of Electronics. Part I.

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The phenomenon of "human consciousness" is considered on the basis of the full electronic interpretation of brain functioning proposed earlier. In the first part of the work the principles of the analysis of the phenomenon, problems and approximations of its description, as well as the essence of the developed theory of human consciousness are presented.

In particular, it has been shown that an accurate analysis of human consciousness is impossible in principle. In this regard, the transition to an approximate consideration of consciousness is actually forced. When considering the phenomenon of "consciousness", strictly speaking, it is necessary to analyze the following complete system: "the brain — other components of the nervous system — the body — the environment." This is related to the fact that the brain, as well as the person as a whole, is an open, dynamic and self-organizing subsystem in this case. Even though consciousness is a product of the brain in accordance with the concept of internalism adopted in the work, other components of the complete system are certainly influencing consciousness, and this influence is not one-sided and can be significant. Therefore a rigorous treatment of the brain functioning is hardly possible. Analysis of known promising approaches to the description of consciousness leads to the conclusion that the use of the full electronic interpretation of the functioning of the human brain proposed by the author is the most realistic way at the present stage of neuroscience development. A theory of human consciousness has been developed on the basis of this interpretation. It is described in detail in this part of the work. Thought and other mental functions are material in accordance with the theory. It is noted that the proposed theory can be attributed to the monistic materialistic theory of consciousness of the emergent type.

Keywords: *human consciousness, brain, full electronic interpretation, nanoelectronics.*

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"It is also useful to know for people that our joys, pleasures, laughter and jokes come not from any other place, but exactly from here (from the brain), from where our grief, melancholy, sorrow and lamentations also come.

And exactly with this part of the body we think and we understand, we see, we hear and we distinguish what is shameful and what is fair, what is evil and what is good, everything that is pleasant and unpleasant, distinguishing all this partly by the established custom, and partly by the advantage, which we get. By this part of the body we distinguish pleasure and burden, depending on the circumstances, and, at that, one and same thing is not always pleasant for us. From the same part of our body we also rave and go crazy, and we feel fears and the horrors, some of them at night, the other ones in the daytime, and also dreams and inappropriate errors, and causeless cares; from here also comes the ignorance of the present affairs, inability and inexperience. And all this comes to us from the brain... "

Hippocrates [1]

Introduction

A person is a supercomplex dynamic selforganizing system. Unfortunately, its rigorous research including modelling, at the microlevel, the cellular level for example, is actually impossible. The situation is aggravated by the fact that because of the openness of the system, it is necessary to take into account the interactions of a person with the environment (including society). As a result, an analysis should be carried out at most varied levels of the description with attraction of a wide spectrum of disciplines (at least, their certain sections), beginning from physics, chemistry, biology, medicine and ending with philosophy. Obviously, in a general case it is even more impossible.

As is known, a human organism is controlled by the nervous system, the main integrating information centre of which is brain. The human brain is fantastically complex object. Thus, the number of the nervous cells in it is about 10^{11}, the number of the synapses equals to $10^{14}...10^{15}$, and the number of the ion channels and molecules is almost 10^{22} per 1 cm^3. The complexity of the problem of the brain functioning is characterised well by the estimation of the total volume of the

information by the number of possible neural states of a book [2]: 2^{NK}, where N — number of neutrons ($N = 10^{11}$), K — number of generations of operation ($K \gg 1$), i.e., it is an "astronomical number". Thus, the research of a brain only is a problem of "monstrous complexity".

Especial result of functioning of this information system of fantastic complexity is the consciousness, the main riddle of Nature. There is an obvious justice in the dialectic law of transition of quantity into quality.

The aim of the given work is consideration of the human consciousness from the point of view of physics, from the point of view of an expert in electronics, in particular. An important role in this will be played by a fully electronic interpretation of the brain functioning and a complex hierarchical approach to its research based on a multilevel modelling in combination with the experimental methods, proposed by the author.

Principles of analysis

During consideration of the human consciousness the author was guided by two principles: 1) "the central dogma" of neurobiology; 2) the economy law or Occam's Razor.

The first one means, "that all normal functions of a healthy brain and all their pathological disorders, whatever complex they are, in the long run, could be explained proceeding from the properties of the basic structural components of the brain" [3]. It is easy to notice, that it is a modern, beautiful and elegant formulation of a brilliant thought, which was stated in an epigraph and expressed over two thousand years ago. I should point out, that similar "working hypotheses" were used by many, including outstanding, researchers of the brain. Hence, the author adheres to the idea of the internalism, according to which "consciousness and qualia are the features of the brain activity and consequently they, in a literal sense, are in the brain" [4]. Numerous data of the neurobiology and neuropsychology testify to this. Certain important areas of a human brain collapse while the consciousness varies essentially or disappears altogether (see, for example, [4—6]).

Use of the economy law or Occam's Razor [7] means, that only the established facts of physics, neurobiology, medicine and some other scientific disciplines will be used as arguments. Thus, we will try to rely on this "minimum", i.e., we will do without employment of the forces form the other world, mythical fields and unreasonable hypotheses, and, in other words, without fantasies.

Besides, other important factors in the consideration will be a full electronic interpretation of the brain functioning and a complex hierarchical approach to its research, proposed by the author, and based on a multilevel modelling in combination with the experimental methods, presented in detail in the works [8—13] and supplemented in the article [14] and the review [15]. I should point out, that many ideas of these works concerning the brain in general will be also used here, but already with reference to the human consciousness.

Problems and approximations

The problems begin with the definition of the concept of "consciousness". The author found a lot of versions in literature. Unfortunately, practically all of them have their drawbacks (excessive generality, floridity, complexity, etc.), which seem to be a consequence of the special many-sided character of the considered phenomenon of Nature and, most likely, are inevitable. Apparently, the most successful and compact definition is the one presented in a monographic textbook, I quote [4]: "The consciousness is the internal flow of the subjective experiences, which is present directly in us and constantly reveals itself to us".

Strictly speaking, during consideration of the phenomenon of "consciousness", it is necessary to analyze the following full system [15]: brain — other components of the nervous system — body — environment. This is connected with the fact that a brain, just like a human organism as a whole (Introduction), is an open, dynamic and self-organizing subsystem. And although according to the accepted idea of the internalism, the consciousness is a brain product, it is also undoubtedly influenced by the other components of the full system, at that, this influence is not unilateral and can be essential. Moreover, during an analysis of the consciousness of a concrete person in a concrete moment of time it is necessary to set the initial data about this system or, at least, full information concerning the brain in the corresponding moment of time. This is hardly possible experimentally. At the same time modeling of the *whole of* the background of development of a brain till the corresponding moment of time is a problem of fantastic complexity and it will also hardly be solved sometime [8].

Therefore, a logical and natural way is a transition to the approximate description of such supercomplex objects as the human brain and the consciousness, in particular. I should point out at once, that there can be many approximations in a description of consciousness. And this is normal, because we talking about the problems, which in mathematics are called intractable of *NP* class [8], i.e. problems of a special degree of complexity.

According to the accepted "the central dogma" of neurobiology, first of all, we will connect the consciousness with a complex of the physical and chemical processes going on in a live human brain and supporting this kind of activity. In the light of what was said above, already this statement is an approximation. Is a description of at least this kind of activity possible? The answer is extremely simple: "Hardly". And there are, at least, two fundamental reasons or problems here: 1) apparently, it is impossible to separate the conscious activity of a brain from the other its numerous functions, mental, first of all, occurring at the same time in parallel, and, most likely, with crossings, i.e. interaction takes place (problem of "uncoupling", see hereinafter, "flexibility of bonds"); 2) the models (idealisations) cannot correspond fully to the objects, the more so, to such complex ones, as human brain and consciousness.

Speaking about the first problem, apparently, its, at least, approximated solution is possible only with application of modelling. The second problem reflects a purely philosophical point of view. In [16] the author called it "the problem of the first step" or beginning of idealisation, and, unfortunately, it cannot be solved in the science, which uses models. Hence, any mathematical modelling of the brain functioning will be approximated. At the same time, absence of a clear and accurate definition of the concept of "consciousness" complicates the situation.

Thus, it is necessary to accept the fact that *the exact description of the human consciousness is impossible in principle, and we are compelled to pass to its approximated description*.

Exactly the impossibility of an accurate description of the consciousness will provide "a fundamental basis for infinite speculations" in the style of "we do not understand something in human consciousness, there is something mysterious here". In order to cool the excitement or pleasure of the sceptics, dogmatists, charlatans and so forth, I will present only two arguments [8]. Firstly, the brain only approximately reflects, or, to be more exact, reconstructs, what really occurs in Nature. Therefore, is it necessary to describe it precisely? The obvious answer is "No". Secondly, even in much simpler device of electronics, such as a TV set, we do not know the behaviour of this or that electron in the device functioning, and we will never learn that, according to the principles of the quantum mechanics, and Heisenberg's uncertainty principle, in particular. Nevertheless, we understand, how the TV set works, we can make it and repair it. In this connection the main and real purpose of studying of the phenomenon of "consciousness", which should, as it seems to me, be posed, is treatment of various mental diseases; in this case it is the disorder of consciousness. I think, that for this purpose an approximated description of the human consciousness is quite enough, because it is really achievable. The success of the human brain medicine testifies to this.

In the light of everything stated above, all the existing theories of consciousness (a good review of the data on consciousness and a systematic presentation of the corresponding theories are given in [4]) should be considered as approximated ones, at that, frequently enough they are rough or simply wrong. Therefore, the attempts for realisation of the exact copies of the human consciousness with a view of their transfer to a computer (a certain version of immortality) should be perceived as a great exaggeration of the real possibilities.

So, which understanding of the human mental functions, including consciousness, will be the most adequate? According to the author, it is the following formulation: "Mental functions, including consciousness, are determined by the energy flows in a human brain, which ensure the corresponding kind of activity". Unfortunately, such an understanding cannot be strictly described even by one of the fundamental reasons specified above. Approximations are still compulsory.

As the most promising for development we will consider the point of view, which became canonical in the neurosciences. Thus, according to the neurophysiological data, the information processing in the brain, as well as various mental functions, are connected with the work of the neural ensembles (hereinafter, circuits). In particular, with reference to the case in point, it is promising to use the concept of research of the neuronal correlates of consciousnesses (NCC), consisting in the definition of "what are the minimal sufficient volumes of the neurons or activity of the nervous system, which necessarily accompany this or that realised experience" [4].

I have to point out, that in this case the principal importance is given to the nervous cells — neurons, and only auxiliary functions are recognized for the other type of the brain cells — neuroglia. Although this assumption also provokes strong objections from certain experts [17], the extensive research undertaken in a number of special brain disciplines testifies to its admissibility [18—20]. And nevertheless, it is clear, that the concept of NCC is an approximation to what actually occurs and is a result of already several steps of assumptions.

Notwithstanding the achieved indisputable success in the neurosciences (neurophysiology, neuropsychology, etc.), unfortunately, at the present moment, there is no universally recognized and causing no doubt theory of consciousness [4], which could be explained by the above-mentioned objective and very serious complexities. However, I will single out the principles from these sciences, most valuable for the further consideration, namely:

1. Principles of higher nervous activity [21]: reflex, dominant, reflection and system activity of the brain.

2. "Even the simplest mental function is a result of the integrative activity of the entire brain" [21].

3. "...The structural basis for the cerebral functions is ensured by the distributed systems. Each function is determined by a certain combination of the cortical and subcortical centers" [18].

Thus, the brain as a whole is a locally-distributed system. Therefore, considerable efforts have been made in order to single out in a brain the subsystems, responsible for these or those functions. From the point of view of the author, the most successful are two partitions [5, 22].

So, the Luriya's theory of the system dynamic localisation of the higher mental functions (memory, perception, thinking, speech are traditionally referred to them) is important. According to the structurally functional model of a brain as a substratum of the mental activity it is divided into three main units (subsystems), namely [5]:

1) A unit for regulation of the level of the brain activity; 2) A unit for reception, processing and storage of the information coming from the external world; 3) A unit for programming, regulation and control of the mental activity. The most important component of the third unit is the prefrontal cortex. A. R. Luriya also pointed out, that any higher mental function is carried out with the assistance of all the singled out units (subsystems).

Another and more modern partition was proposed by Doctor D. Amen, well-known American neurophysiologist and neuropsychiatrist, one of the pioneers of the use of the computer tomography in psychiatry. He divided a brain into five subsystems*, namely [22]: 1) deep limbic subsystem; 2) basal ganglia; 3) prefrontal cortex; 4) cingular subsystem; 5) temporal lobes of a brain. Amen also underlines, that the subsystems do not exist separately. "They are connected among themselves by millions of complex bonds. Each time, when one system* is injured, the other ones, most likely, will also be involved in the process " [22]. The applied method of visualisation of a brain allowed us not only to single out its subsystems, but, which is the most important, to develop on this basis rather effective therapeutic methods for treatment of many mental frustrations of concrete patients. In my opinion, the given approach has good prospects in psychiatry, especially in the process of improvement of the qualities of the tools for visualisation of a human brain. As a whole, despite all the conditionality of the partition of a brain into subsystems, it will also be useful, at least, at the initial stages of mod-

* D. Amen uses the term "system". The term "subsystem" will be more accurate for us.

elling of various brain functions. Should we at once model the whole of the brain during consideration of separate mental functions? However, it will hardly be possible (see further).

Full electronic interpretation of the brain functioning

As it has already been mentioned, the conscious activity is determined by all the complex of the physical and chemical processes, which go on in the human brain and ensure its support. Unfortunately, it is a "tangle" of numerous processes. Strictly speaking, they are influenced by all the forces of Nature. Since we connect the mental functions with functioning of the neural circuits, then the following interconnected processes can render influence on their work: the electric, chemical, mechanical, thermal and other processes. I should point out, that traditionally in neurobiology they single out the chemical and electric processes [18, 19] (therefore, quite often, a brain is called "an electrochemical device"), at that, as a rule, the preference is given to the chemical ones. From what was said above it is clear, that they can actually be only the usually dominating processes. Even in case of such simplification it is still difficult to "unwind" the remaining "tangle".

For an attempt to do this, a full electronic interpretation of the human brain functioning [8—15] is offered.

As its basis, hypothesis 1 was accepted: it is considered, that the dominating influence on the brain functioning is rendered by the electric processes. Thus, it is assumed, that the information processing in a brain goes basically at the level of the electric processes. The chemical processes ensure a power supply of the electric (neural) circuits of the brain, and also their modification.

It was demonstrated, that *the whole* neural circuit of the brain can be interpreted as a nonlinear electric circuit (the first type), possessing the following basic properties: 1) At first a neural circuit is a growing and then a modifying electric circuit (the main difference from the integrated circuits (IC) of the solid-state electronics — electric circuits of the second type); 2) A nonlinear electric circuit of the first type is characterised not only by an extremely complex topology, but also by a variation of properties of its components, which seem to be the same type of elements (bodies of cells, axons, dendrites, spinules, synapses, etc.); 3) The electric circuits of the first type can demonstrate a big variety in their behavior, dependending on both the incoming signals and the signals passing through them; 4) From the point of view of electronics, the brain of an adult person is, first of all, a set of nonlinear electric (neural) circuits of two kinds, which should not be modified and which can be modified.

The key (active) elements in the electric (neural) circuits of the brain are the ionic channels. In this connection I will present several quotations from a brilliant textbook on neurobiology, namely [19]: "For a successful functioning of the nervous system, the neurons should possess a very diverse repertoire of the electric activity... In the long run, all these versions depend on activation or deactivation of the ionic channels regulating the ionic currents through the membranes of the nervous cells". A certain contribution to the transfer of ions is also made by the other channels (carriers) — ionic pumps, exchangers [19]. And nevertheless, "it is necessary to consider the ionic channels as the systems conducting the electric signals, and the carriers — as the systems ensuring the basic conditions, which make such a behaviour possible" [19]. I should point out, that already now a big number of various types, kinds and subsorts of channels [19, 23] are known.

The ionic channels are complex nano-electromechanical systems (NEMS) [8]. This is connected with the following principal reasons: 1) the characteristic sizes of all the structures forming the ionic channels, are within the nanometer range [19, 23]; 2) the conformational transitions of the proteins and/or their subunits (domains), leading to passing of the ions, are the processes initiated by the electric signals, in which the mechanical forces [23] are important. The physics of these transitions is rather complex [23], however, the most interesting thing is that these NEMS can control the passage of separate ions (the basic ones are the ions of potassium, sodium, calcium and chlorine) with characteristic sizes already in the angstrom units, i.e. less than 1 nm. The other channels are also complex NEMS, the ionic pumps, in particular.

Hence, *according to the proposed interpretation, the active elements are different channels, i.e. NEMS, conducting the ions and defining the brain electronics, while the brain as a whole can be considered as an object of organic hybrid nanoelectronics* [8, 16]. In this connection I will point out the basic difference from IC of the solid-state micro- and nanoelectronics, in which the active elements are diodes and transistors. Thus, Nature opted for a qualitatively different way. At the same time the neurons themselves, forming the neural circuits, are already much more complex integrating devices, and, figuratively speaking, their analogues are whole IC. Therefore, the interpretation of the neurons as the basic active elements of the brain (in neuronsciences a neuron is frequently compared to a transistor) is a great simplification from the point of view of the electronics. Everything is much more complex.

It is interesting to estimate, at least roughly, the level of integration of a human brain as an object of electronics. The estimation is done, as is customary in the micro- and nanoelectronics, by the number of the active elements. Since the number of the neurons in the brain is about 10^{11}, the number of the channels conducting ions, i.e. active elements, will be roughly by 8—10 orders more*, i.e. we are talking about figures in the range of $10^{19}...10^{21}$. Now, we can correct the assessment of the work [2] (Introduction) of the total volume of information by the number of the possible states, but already the number of the channels (open-closed) is equal to 2^{MK}, where M — number of channels (we take the bottom limit of $M = 10^{19}$), K — number of the generations of actuation ($K \gg 1$), i.e. we have even a much more grandiose figure. Hence, the human brain is an object of nanoelectronics of a fantastic level of integration. No wonder, that exactly such a system — a masterpiece of electronics created by Nature, — also generates the consciousness (with the specified reservations). It is easy to notice, that a rigorous modelling of such a system and in the given approximation is also impossible [8].

An approximate functioning of the human brain was considered within the framework of the proposed full electronic interpretation. In particular, three types of the operating

* Unfortunately, the author could not find the necessary data in literature. The estimation is made by the number of ionic channels in the axon of squid ~10^{10} [24].

modes of the brain as a set of nonlinear electric circuits, were named: 1) under an external influence; 2) without an external influence (internal); 3) mixed. All the separate operating modes, including perception, recollection, thinking and other mental functions, belong to one of the specified types. At the same time *any specific operating mode of a live brain, including the mental functions, is a result of the passage of an electric signal (signals) through the corresponding set of the electric (neural) circuits*, which integrates the modes, i.e. is a common feature for all of them*. At that, the basic operations are comparison, coding, decoding, action command, and modification of the neural circuits.

In particular, a thought is a decoding (internal reproduction) of the electric signal (signals), initiated by the brain and passing via various neural circuits of the brain of the corresponding spatio-temporal configuration [8, 11]. Hence, a thought is an original reverse process in relation to the processing of the arriving information (direct process), which is initiated, apparently, mainly by the cerebral cortex, i.e. the currents go via the neural circuits, causing a decoding of the information contained in the corresponding neural circuits.

In psychology there are two systems of thinking [25]: system 1 (automatic) and system 2 (arbitrary). "*System 1* works automatically and very quickly, it requires no effort or almost no effort, without a feeling of the intended control. *System 2* uses the attention, necessary for the conscious intellectual efforts, including complex calculations. Actions of system 2 are often connected with a subjective sensation of activity, choice and concentration... System 1 is impulsive and intuitive, while system 2 is capable to reasonings..." [25]. It is possible to assert, that the automatic system functions at a subconscious level, while the arbitrary system — with participation of an awareness.

It is convenient to present the cogitative activity as a whole occurring by a "spiral" (one of the possible versions of "a flow of consciousness"**). So, one turn of a spiral of the work of the automatic system (system 1) is presented on fig. 1. First comes planning (modelling or prediction) of a situation, and then — action. The process can go on further. The work of the arbitrary system (system 2) is more varied and complex. Several versions of one turn of a spiral are presented in fig. 2. In the first version (fig. 2, *a*) planning (modelling or prediction) of a situation comes first, then — action (its control of the brain, to be more exact), and after that — awareness. Exactly this version caused the most turbulent discussion in the neurophysiological literature (the well-known Libet experiments of 1980s concerning "the free will" [2]). Action comes first, and then — awareness. However, I should point out, that, first of all, the awareness is necessary for realisation of the control and managing functions, and can be switched on at various moments of time of "the spiral" of the cogitative activity, in attempt to make it more effective and qualitative. A simpler version of the work of system 2 is also possible (fig. 2, *b*). Planning (modelling or prediction) of a situation, and then — awareness.

It is obvious, that very complex "spirals" of the cogitative activity can only be generated from the above versions of the turns of spiral. It is also necessary to point out, that the situations and actions themselves can be divided into components (split into pieces), which complicates consideration of the process of thinking even more.

I should underline, that the consciousness is, undoubtedly, a systemic, integrative property of the human brain, which is supported by many areas, however, an analysis of numerous (mainly experimental) data of the neurosciences (neurophysiology, neuropsychology, etc.) allows us to draw a conclusion, that, apparently, the area, first of all responsible for the awareness, is the prefrontal cerebral cortex. Hence, the initiation and possible follow up of the cogitative activity in case of work of system 2 occurs in the neural circuits of this area, and then a flexible linkage is carried out with the neural circuits of various structures and areas of the brain, depending on the character of the thought. If this thought provokes any action, then for its awareness the information should come for processing to the prefrontal cerebral cortex. As a result there is a natural delay, which explains the Libet experinents (see Part II), also a slower and less efficient functioning of system 2 in comparison with the economic system 1 characterised by a mass parallelism in the work.

The flexibility of linkage is reached, at least, at three levels [14]: 1) the bonds between the areas and/or structures of the brain; 2) the neural ensembles (various neural ensembles can participate in the work in the areas and structures of the brain); 3) neurons (the neurons themselves are also multifunctional). And this means, that the support to different mental functions can be provided by the same areas (their subareas), neural circuits (their elements), and, apparently, even separate neurons. This complicates greatly the analysis and leads to a problem of "uncoupling" of the mental functions (see earlier).

According to the stated above, in my opinion, a sharp contradistinction of the conscious and subconscious activities of the brain is incorrect. The basic distinction consists mainly in the fact that in case of the work of system 2 the participation of the neural circuits of the prefrontal cerebral cortex, responsible for awareness, is necessary.

Consequently, a conscious thought is a decoding (internal reproduction) of the electric signal (signals), initiated by the brain itself and passing via NCC of the brain of the corresponding spatio-temporal configuration, i.e. the currents pass through the neural circuits, causing appearance of images, concepts, etc. as a result of decoding of the information, contained in the corresponding neural circuits. Thus, *usually, thinking is an internal perception by a person of the information coded in the brain itself [8, 11], and "the cogitative activity, apparently, is the essence of the macroscopical collective phenomena in the nonlinear electric circuits of the first type" [8, 13], i.e. a thought in the human brain is material! And, as it follows from the above, the other mental functions are also material.*

In accordance with the classification [4], the proposed theory within the framework of the full electronic interpretation of functioning of the human brain can be referred to the monistic materialistic theory of consciousness of the emergent type [14]. I should point out, that in the given theory it becomes clear, what a thought is. I think that the presented definition of a thought is quite a good approximation to the truth.

* This set of circuits for the mental function can be called a neural correlate of the mental function (NCMF) by analogy with NCC.

** The term was introduced by W. James, outstanding American psychologist and philosopher.

At the same time the opinion of the neuroscientists on the question considered in the work as a whole is quite well expressed in the following citation [26]: "We can assert, that the consciousness and the brain correlate from the point of view of the functions, however, we actually do not know, in which ways the brain activity and the functions of consciousness mutually create each other.

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